AFRL-HE-BR-TP-2000-0001

UNITED STATES AIR FORCE RESEARCH LABORATORY

Inferring Saving in Training Time From Effect Size Estimates

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February 2000

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 2000	Interim-Oct 1996—Sept 1997

4. TITLE AND SUBTITLE
Inferring Saving in Training Time From Effect Size Estimates

5. FUNDING NUMBERS
PE – 62203F
PR – 2313
TA – C1
WU – 00

6. AUTHOR(S)
Burke Burright

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Human Effectiveness Directorate
Mission Critical Skills Division
Brooks Air Force Base TX 78235-5118

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AFRL-HE-BR-TP-2000-0001

11. SUPPLEMENTARY NOTES
Air Force Research Laboratory Technical Monitor: Dr. Burright, (210) 652-6811, ext 3025

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Asynchronous training technologies enable students to master material much more rapidly than classroom instruction. Students' time saving represents a major potential benefit of using them.

This paper fills a methodology gap in estimating the students' timesaving benefit of asynchronous training technologies. Meta-analyses of their effectiveness yield a statistic called Effect Size. Estimating the benefit in dollar terms requires information regarding the reduction in total training time. This paper presents a methodology for inferring the percentage reduction in students' training time from estimates of Effect Size. It goes on to infer the percentage reductions for three asynchronous training technologies from estimates of their Effect Sizes. Finally, it compares the estimates to some direct measures of training time savings.

14. SUBJECT TERMS
Training technologies interactive courseware (ICW) Time saving benefits
Intelligent computer aided instructions (CAI) Effect Size

15. NUMBER OF PAGES
13

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. Z39-18
298-102

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Inferring Saving in Training Time from Effect Size Estimates

I. Introduction

Since at least the 1970's, cognitive psychologists, computer scientists, and educators have been developing software technologies for training. Moreover, they have shown that many of these technologies are significantly more efficient that standard classroom instruction.

Users can reap the benefits of more efficient instructional technologies either as increased student achievement or as reduced training time. Most empirical evaluations have expressed the efficiency gains in terms of achievements. This technical paper lays out a method for using this data on achievement gains to estimate reductions in training times. For each instructional technology, the method can provide a curve for trading-off achievement and training timesavings.

Several researchers have provided reviews and analyses of the empirical studies documenting the achievement gains and training timesavings. They include Orlansky and String (1979), Kulik, Kulik, and Shwalb (1986), Niemiec and Walberg (1987), Fletcher (1990), Redding and Fletcher (1994), Metzko, Redding, and Fletcher (1996), and Regian, Seidel, Schuler, and Radtke (1996). These reviews and analyses show remarkably consistent results for particular instructional technologies. This paper uses their results and my method to estimate training timesavings for three asynchronous training delivery technologies.

II. Methodology

Effect Size. The analyses and reviews have made empirical studies comparable by converting them to an effect size (E) metric. For our purposes, it can be defined as the standardized mean difference in achievement of the group trained with asynchronous instructional technology (A_t) and the group trained with standard classroom instruction (A_c). Thus,

$$E_t = (A_t - A_c)/ S_c \qquad (1)$$

where S_c is the standard deviation of the group trained with stand classroom instruction.

Time Savings. Holding instructional time constant, the relative achievement of students training with technology t is A_t / A_c , which is assumed to be equal to or greater than one. So, students would learn in $1/(A_t / A_c)$ hours what they had learned in one hour of classroom instruction. Thus, the proportional time savings $((T_c - T_t)/ T_c)$ is

$$1 - (1/(A_t / A_c))$$

or

$$1 - (A_c / A_t)$$

or

$$(A_t - A_c)/ A_t \qquad (2)$$

Using Expression 1 to eliminate the expression $A_t - A_c$ from Expression 2, we get the following for the proportional time savings due to using instructional technology t,

$$(E_t \; S_c)/ A_t \qquad (3)$$

We can Expression 3 to estimate time saving for instructional technology t.

The estimates of effect size are based on normalized standard deviation of 0.34 ($S_c = 0.34$). Substituting,

$$(T_c - T_t)/ T_c = 0.34 \, E_t / A_t \qquad (4)$$

Algebraic manipulations gives us

$$T_t = T_c - (0.34 \, E_t \, T_c) / A_t \qquad (5)$$

If we focus on an hour of classroom instruction, we can write $T_c = 60$ minutes. Substituting,

$$T_t = 60 - (20.4\, E_t / A_t) \qquad (6)$$

Equation 6 describes a trade-off relationship between training time for technology t (T_t) and desired average achievement using technology t (A_t). The only parameter is the effect size of technology
t (E_t).

The estimates of effect size are based on a standardized mean achievement for the classroom group of 0.5 ($A_c = 0.5$). An assumption of unchanged achievement implies that $A_t = 0.5$. Substituting in Equation (4), we get the following equation for proportion timesavings:

$$(T_c - T_t)/ T_c = 0.68\, E_t \qquad (7)$$

Substituting in Equation (6), we get the following equation for the number of minutes of instructional time required to provide the same amounts of training and achievement as one hour of class room instruction:

$$T_t = 60 - 40.8\, E_t \qquad (8)$$

III. Estimates of Time Savings

Interactive Courseware (ICW) provides instructional materials to students individually (1). Instruction is self-paced. ICW provides interactions that tailor the instruction to the needs of individual students. Each student receives that level of detail, pace, remediation, sequence of topics, and interactions needed to learn the material. ICW encompasses computer-based instruction (CBI), CD-ROM instruction, and interactive videodisc instruction.

Researchers have made much progress in estimating the effect size of ICW. Redding and Fletcher (1994, pp. 75-6) discuss meta-analyses and reviews of CBI effectiveness. They find that the most relevant meta-analyses and the broadest reviews suggest an average effect size of 0.42 for CBI. Fletcher (July 1990, p. III-10) gets an average effect size of 0.44 in his meta-analysis of interactive videodisc instruction. In a forthcoming meta-analysis of ICW in military training, the Institute for Defense Analysis (IDA) will report an effect size of 0.44 (Metzko, Redding, and Fletcher, December 1996, p. D-3).

Through based on different data sets, these estimates of effect size are remarkable close. Let's use an effect size of 0.44 to compute our estimates of timesavings. Substituting this value into Equations 7 and 8, we get an average timesaving of 30 percent for ICW and an average time of 42 minutes to provide the equivalent of an hour of conventional instruction. This average time savings is consistent with Orlansky and String's (April 1979, p. 5) finding that students instructed by CAI save about 30 percent of the time required to complete the same courses given by conventional instruction.

The timesavings provided by ICW may arise primarily from its self-paced character, which frees more able students from the common pace of the classroom. So, ICW's timesavings may reflect primarily the more able students getting through the materials more rapidly.

Tutorial ICW. In his 1990 study, Fletcher (pp. III-11 to III-15) found that ICW that used a directive and tutorial approach has significantly large effect sizes. (The reader should not confuse Tutorial ICW with intelligent tutors. None of this instructional courseware had student, expert, or instructional models. The tutor components of many standard software programs are examples of tutorial ICW.) He estimated an average effect size of 0.68 for tutorial ICW. Substituting this value into Equations 7 and 8, we get an average timesaving of 46 percent for Tutorial ICW and an average time of 32 minutes to provide the equivalent of an hour of conventional instruction.

Intelligent Computer Aided Instruction (ICAI). Evidence on the effect size of ICAI is much more limited. Only three studies have provided estimates (Regian, Seidel, Schuler, and Radtike, 1996, pp. 11-13). All three are very close to one. Substituting this value into Equations 7 and 8, we get average timesavings of 68 percent for ICAI and an average time of 19 minutes to provide the equivalent of an hour of conventional instruction. This estimate of average timesavings may be

high. Regian, Seidel, Schuler, and Radtike report average timesavings of 55 percent for three evaluations of ICAI in higher education.

IV. Using the Estimates in Benefit/Cost Analysis

Reductions in training time have implications for estimating both the benefits and the costs of using asynchronous instructional technologies. On the benefit side, they mean that less student and instructor time must be devoted to training. (Office of the Under Secretary of Defense (P&R)) This savings may represent the quantitatively most important benefit of using the new technologies.

`On the cost side, development hours per hour of instruction drive the cost of developing courseware and materials. The more efficient instructional technologies require more development hours per hours of instruction. However, their greater efficiency means that fewer hours of instruction are required to provide a given amount of training. This reduction will offset, in whole or in part, the greater number of development hours per instructional hour.

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Presents meta-analysis of studies of effectiveness. Application of its results not limited to IVD. One can apply its results for instructional approaches, instructional setting, and level of interactivity to other asynchronous training technologies.

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Appendices A to E summarize IDA's and other evaluations of the effectiveness of interactive courseware and evaluations of military video teletraining (VTT).

Niemiec, R., & Walberg, H. J. (1987). Comparative Effects of Computer-Assisted Instruciton: A Synthesis of Reviews. Journal of Educational Computing Research, 3, 19-37.

Orlansky, Jesse, & String, Joseph (April 1979). Cost-Effectiveness of Computer-Based Instruction in Military Training (IDA Paper P-1375). Arlington, VA: Institute for Defense Analyses.

A path breaking paper on the effectiveness of computer-based instruction. First paper to identify a 30 percent saving in instructional time. A classic in careful scholarship. Today, paper must be viewed as dealing with only basic computer-based training systems.

Redding, G. A., & Fletcher, J. D. (1995). Technical and Administrative Issues in Distributed Training Technology. In R. J. Siedel and P. R. Chatelier (Eds.) Learning without Boundaries: Technology to Support Distance/ Distributed Learning (pp. 73-93). New York; Plenum Press, 1995.

Contains a summery of literature on the effectiveness of interactive courseware. It also provides a good discussion of the administrative. implementation, and technical issues.

Appendices A to E summarize IDA's and other evaluations of evaluation of the effectiveness of interactive courseware and evaluations of military video teletraining (VTT).

Regian, W., Seidel, R., Schuler, J., and Radtke, P. (1996). Functional Area Analysis of Intelligent Computer-Assisted Instruciton. Training and Personnel Systems Science and Technology Evaluation and Management Committee (TAPSTEM).

Summarizes results on the effectiveness of computer-aided instruction (CAI) and compares them to the effectiveness of intelligent computer-aid instruction (ICAI). Brings together the few results on the effectiveness and instructional timesavings stemming from ICAI.